Air Resources Technical Report for the Betze Project Environmental Impact Statement

ENSR Consulting and Engineering
Fort Collins, Colorado

Prepared for

USDI Bureau of Land Management
Elko District Office
Elko, Nevada

January 1991

AIR RESOURCES TECHNICAL REPORT FOR THE BETZE PROJECT ENVIRONMENTAL IMPACT STATEMENT

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1.0 INTRODUCTION

This technical report provides supporting information related to the air quality sections of the environmental impact statement (EIS) prepared for the Barrick Goldstrike Mines' proposed Betze Project. The EIS provides a summary of the technical methods and results of the air quality analyses. This report provides details and calculations supporting the derivation of the input to those analyses and is intended to provide technical data of sufficient detail to permit an air quality professional to make an independent judgement regarding the analyses which support this EIS.

2.0 TECHNICAL METHODS

This section provides details on the technical methods, procedures, and other data related to the Betze Project EIS air quality analyses. The following topics are covered.

- Emissions Inventory
- Emissions Apportionment
- Meteorological Inputs
- Receptor Selection
- Dispersion Model Selection and Application

2.1 Emissions Inventory

An emissions inventory is the estimation of the quantity of air emissions released by various activities at the Betze Project. The emissions inventory is divided into three components: 1) fugitive dust from mining operations, 2) point source emissions, and 3) mobile source emissions.

2.1.1 Fugitive Dust

Emissions of fugitive dust from the Betze Project were estimated using available emission factors (EPA 1985) for mining operations and operating parameters from the proposed Plan of Operations. Table 2-1 summarizes the emission factors used in the study. Since emission factors specific to precious metals mining operations are not available, factors for operations from surface coal mines were used instead. These emission factors allow for corrections based on material characteristics such as silt content, moisture content, etc.; thus, the use of coal factors is considered appropriate for the analysis.

The selected emission factors were combined with operating data to derive the total particulate matter emission estimates for mining operations. These calculations are summarized in Table 2-2. For PM-10, emissions were based on an estimated PM-10 to TSP ratio of 0.36. This is a composite estimate from data available on other mining operations and general data from EPA's emissions factor document on fugitive dust emissions (AP-42, Section 11). For materials handling, the PM-10 fraction was estimated at 60 percent, based on data in AP-42, Section 8.23.

The operating data used to make these emission estimates were from projected 1991 operating parameters. The 1991 operating year is expected to be the year of highest volume of ore and waste rock removal. Thus, 1991 is expected to be the worst-case year in terms of fugitive dust emissions.

TABLE 2-1

TSP Emission Factors Used for Betze Project Mining Operations

Operation	Equation	Factor	Reference
Drilling	---	1.3 lb/hole	AP-42, Table 8.24-4
Blasting - Ore - Waste	$961\ A^{0.8}/D^{1.8}M^{1.9}$	341 lb/blast 171 lb/blast	AP-42, Table 8.24-2
Material Handling	---	0.01 lb/ton	AP-42, Table 8.23-1
Haul Trucks	$0.0067\ W^{3.4}L^{0.2}$	6.2 lb/VMT	AP-42, Table 8.24-2
Water Trucks	$5.79/M^{4.0}$	0.009 lb/VMT	AP-42, Table 8.24-2
Road Maintenance	$0.040\ S^{2.5}$	5.2 lb/VMT	AP-42, Table 8.24-2
Wind Erosion	---	0.38 ton/acre-year	AP-42, Table 8.24-4

TABLE 2-2

Betze Project Fugitive Dust Emissions

Operation	Emission Factor	Operating Parameter	Percent Controlled	TSP Emissions	PM-10 Fraction	PM-10 Emission
Drilling	1.3 lb/hole	150 holes/day	0	8.1 lb/hr	0.36	2.9 lb/hr
Blasting - Ore	341 lb/blast	1 blast/day	0	14.2 lb/hr	0.36	5.1 lb/hr
Waste	171 lb/blast	1 blast/day	0	7.1 lb/hr	0.36	2.6 lb/hr
Truck Loading	0.01 lb/ton	108.66 MMtons/year	0	124.0 lb/hr	0.6	74.4 lb/hr
Truck Hauling	6.2 lb/VMT	848,646 miles/year	85	90.0 lb/hr	0.36	32.4 lb/hr
Truck Unloading	0.01 lb/ton	108.66 MMtons/year	0	124.0 lb/hr	0.6	74.4 lb/hr
Wind Erosion	0.38 Ton/acre-year	2,192 acres	0	190.2 lb/hr	0.36	68.5 lb/hr

2.1.2 Point Source Emissions

Point source emissions refer to those emissions which emanate from stacks, vents, and other stationary emissions sources. Emissions from point sources include both particulate matter (PM) from operations such as ore crushing and processing, plus gaseous emissions such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and carbon monoxide (CO) from combustion of fuels and processing of sulfur-bearing fuels. Also, minor quantities of unregulated pollutants, known under the generic name of "air toxics," also occur from operations at the Betze Project. These may include trace metals commonly found in the particulate emissions and sulfur compounds other than SO_2 which result from processing of sulfur-bearing ores.

Point source emissions are regulated through a permit system maintained by the Nevada Division of Environmental Protection (NDEP). These permits generally place limits on the emissions of any processing equipment and specify the type of emission controls which must be used. In some cases, limits may also be placed on equipment throughput and hours of operation at each source. Mechanisms for emission testing and maintaining compliance with emissions limits are also specified in the permit.

For the Betze Project, emissions limits contained in the various air quality permits provide for a maximum allowable emission for each of the regulated pollutants. These maximum allowable emissions were used to establish emissions for the various Betze Project point sources. These data are summarized in Table 2-3.

2.1.3 Mobile Sources

Emissions from mobile sources can be significant from mining equipment. The principal pollutants released by these sources are NO_x and CO. Emissions from mobile mining equipment were estimated from EPA (1985) factors for heavy-duty construction equipment (AP-42, Volume II, Section 7) and estimated diesel fuel and gasoline fuel use from the Betze Project Plan of Operations. These emission estimates are summarized in Table 2-4.

The air quality standard for NO_x pertains only to nitrogen dioxide (NO_2). Typically for combustion sources, only a small fraction (generally less than 10 percent) of the NO_x emitted actually occurs as NO_2. Through atmospheric chemical transformation processes, some additional NO_x may also be converted to NO_2. However, the location of the maximum impact from mining equipment is predicted to occur very close to the source, giving little opportunity for such conversion to take place. For this analysis, a NO_2-to-NO_x ratio of 0.25 was assumed. This is believed to provide a very conservative approximation of actual NO_2 levels from emissions of mining equipment.

TABLE 2-3

Summary of Betze Project Point Source Emissions

		Allowable Emissions (lb/hr)			
Permit	Source	PM/PM-10	SO_2	NO_x	CO
1457	ADR Carbon Reactivation Kiln	1.2	0.01	6.2	1.6
1620	Mill Crushing System	1.86			
1620	Mill Reclaim Hopper	0.12			
1620	Mill Lime Silo	2.6			
1621	Heap Leach Crushing System	15.93			
1621	Cement Silo-Heap Leach	13.6			
1622	Melting Furnace (electric)	1.6			
1624	Carbon Reactivation Kiln	1.6	0.01	7.1	1.8
2117	Autoclave	0.5			
2118	Boiler	0.25	0.001	0.6	0.2
2119	Lime Storage/Loading	0.08			
2119	Lime Storage/Discharging	0.24			
2350	ADR Furnace (electric)	1.2			

TABLE 2-4

Betze Project Mining Equipment Emissions

Fuel Type	Fuel Use	CO Factor	CO Emission	NO_x Factor	NO_x Emission
Diesel	13,000,000 gallons/year	153.51 lb/1,000 gal	227.8 lb/hour	368.01 lb/1,000 gal	546.1 lb/hour
Gasoline	312,000 gallons/year	3960.0 lb/1,000 gal	141.0 lb/hour	95.8 lb/1,000 gal	3.4 lb/hour
TOTALS			368.8 lb/hour		549.5 lb/hour

2.2 Emissions Apportionment

Emissions apportionment refers to the procedures used to determine the geographic distribution of emissions across the project area. This is relatively simple for stationary sources like crushers and other process equipment which have a fixed location. For stationary sources, the location of each source can be determined from a site plan and the coordinates measured for input to the model. However, for mining activities and mobile sources, these emissions vary both spatially and temporally. An accurate quantitative assessment of these emissions using a dispersion model requires that the geographic distribution of emissions be as accurate as possible.

2.2.1 Fugitive Dust Emissions

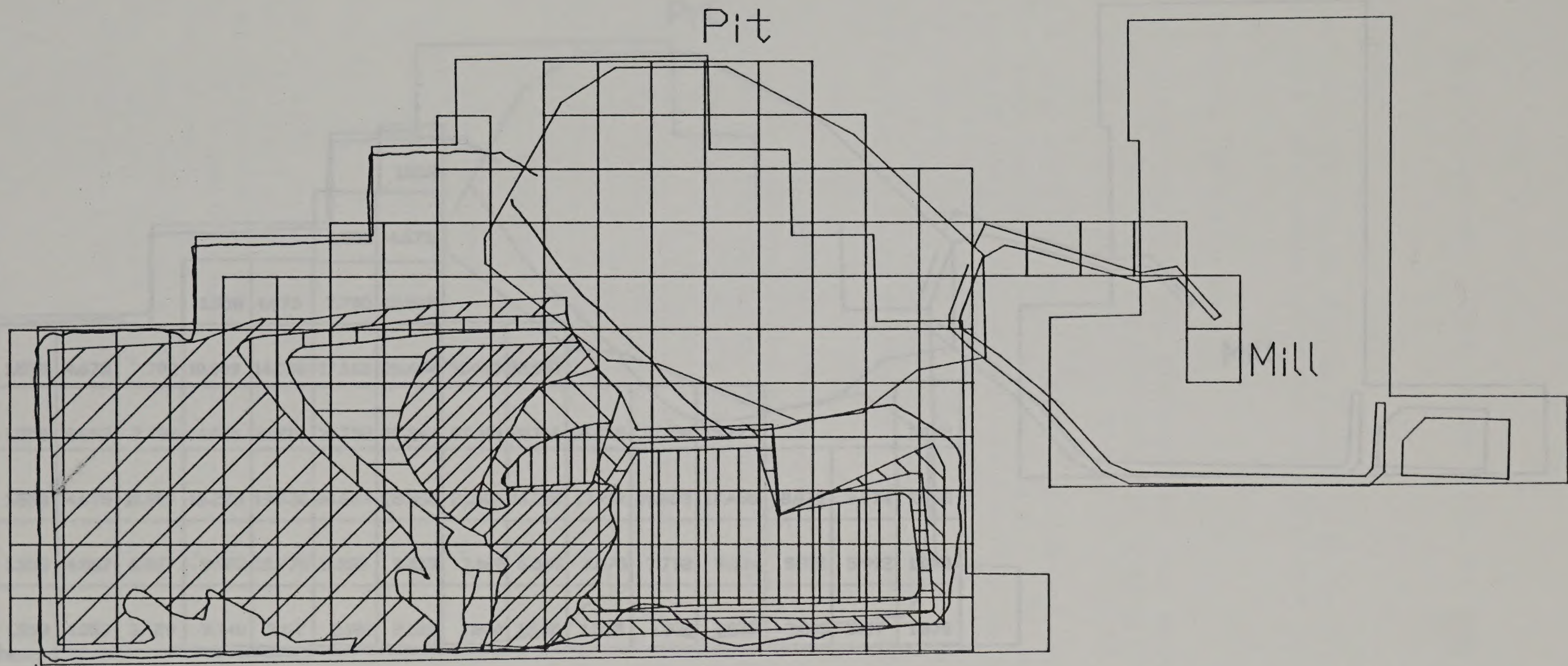
The major sources of fugitive dust emissions at the Betze Project are the pit activities and waste rock disposal areas. This includes truck loading of ore/waste at the pit, truck hauling over unpaved roads, emissions from truck unloading of ore/waste, and wind erosion from disturbed areas in the pit and on the waste pile.

Figure 2-1 shows the layout of the Betze Pit and proposed waste rock disposal areas. A 250-meter by 250-meter grid has been overlayed on this diagram, which represents the emission grids used in the model. The emissions apportionment scheme will determine the appropriate emission rate for each grid square to be input to the dispersion model.

As described previously, the estimates of emissions for fugitive dust have been based on expected 1991 operations. This is the highest emission year because the maximum ore and waste volumes will be handled this year. As such, the 1991 operations represent the worst-case in terms of fugitive dust mining emissions.

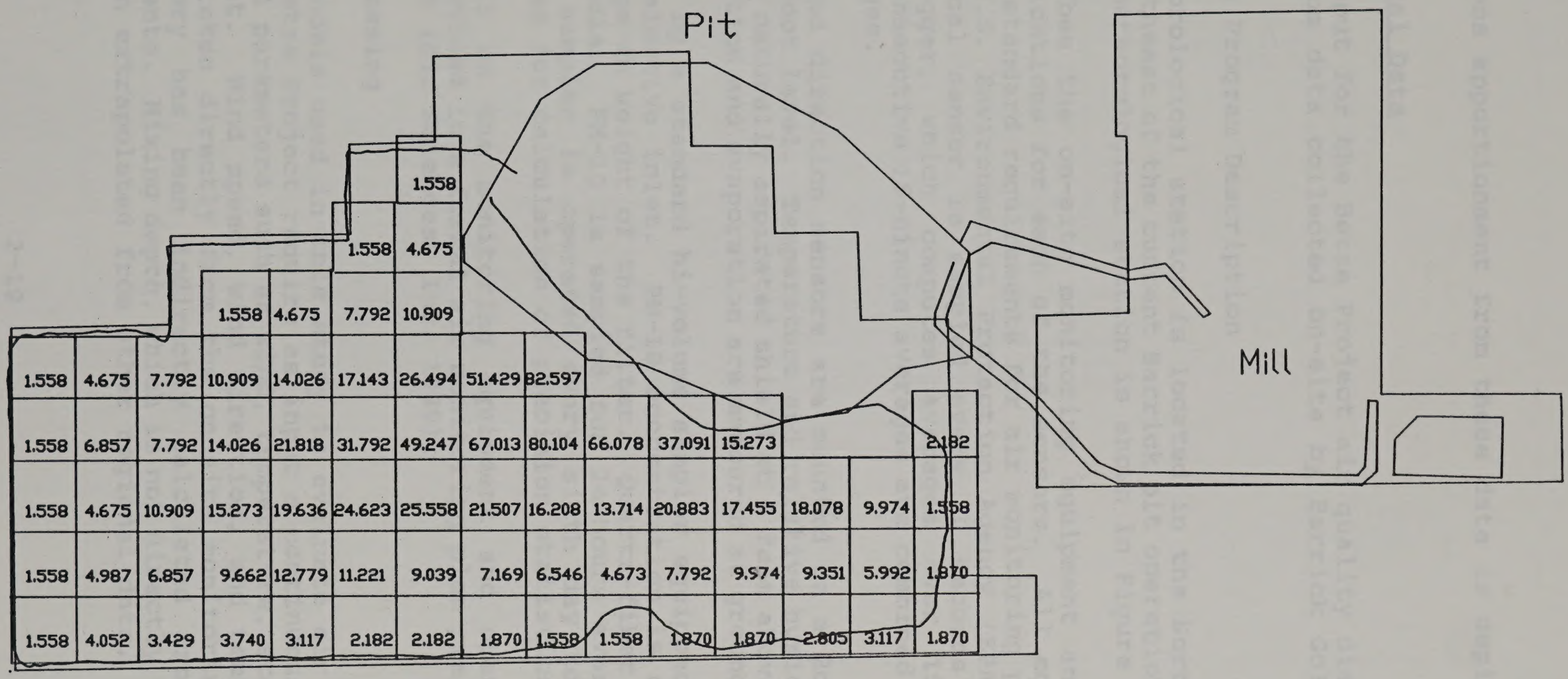
In 1991, the waste rock disposal areas will have several tiers or levels from which operations will occur. These are also shown in Figure 2-1. Because of these tiers, emissions from the waste pile will be separated vertically as well as horizontally. Each emission grid was assigned an elevation based on these data from the plan of operations. Similarly, the pit area will vary in elevation depending on the level of "benches" within the pit.

Within the waste rock disposal areas, emissions come from dumping as well as truck travel. Dumping occurs somewhat uniformly across the pile, but truck travel is highest near the entry point and then spreads out toward the edges. This pattern is depicted in Figure 2-2, which shows the travel patterns across the waste rock disposal area. The majority of emissions occur near the dump entry point in the north center of the waste rock disposal area. Emissions are at a minimum near the edges.



Extended South Waste Disposal Area

Figure 2-1. Layout of the Betze Pit and Waste Disposal Area



Extended South Waste Disposal Area

Figure 2-2. Waste Area Vehicle Mile-Tons Traveled Per Year (Billions)

The final emissions apportionment from these data is depicted in Figure 2-3.

2.3 Meteorological Data

Meteorological input for the Betze Project air quality dispersion modeling come from data collected on-site by Barrick Goldstrike Mines Inc.

2.3.1 Monitoring Program Description

The Barrick meteorological station is located in the North Block about 2 miles northeast of the current Barrick pit operations. The location of the meteorological station is shown in Figure 2-4.

Table 2-5 describes the on-site monitoring equipment and gives technical specifications for each of the sensors. All equipment meets or exceeds standard requirements for air monitoring programs imposed by the U.S. Environmental Protection Agency (EPA 1987). Each meteorological sensor is sampled every 10 seconds by the on-site data logger, which computes averages over 15-minute periods. Four consecutive 15-minute averages are combined to form the hourly averages.

The wind speed and direction sensors are mounted on a Rohn 25-G tower at the 30-foot level. Temperature and relative humidity are measured within a naturally aspirated shield at 6 feet above ground level. Precipitation and evaporation are measured at ground-level.

PM-10 is sampled by a standard hi-volume sampler equipped with a 10-micron size-selective inlet. PM-10 concentration is obtained via the net change in weight of the filter. Quartz-fiber is used as the filter media. PM-10 is sampled for 24-hours every third day. A second sampler is operated every sixth day to obtain collocated samples for calculation of precision statistics.

Additional detail on the monitoring equipment and operational protocols are provided in a formal air monitoring plan prepared on behalf of Barrick (Air Sciences, Inc. 1989).

2.3.2 Data Processing

The dispersion models used in this study to evaluate air quality impacts of the Betze Project require as input a continuous record of meteorological parameters such as wind, temperature, stability, and mixing height. Wind speed, wind direction, and temperature data have been taken directly from the on-site monitoring data. Stability category has been indirectly calculated from basic on-site measurements. Mixing depth, which is not directly measured on-site, has been extrapolated from other regional data.

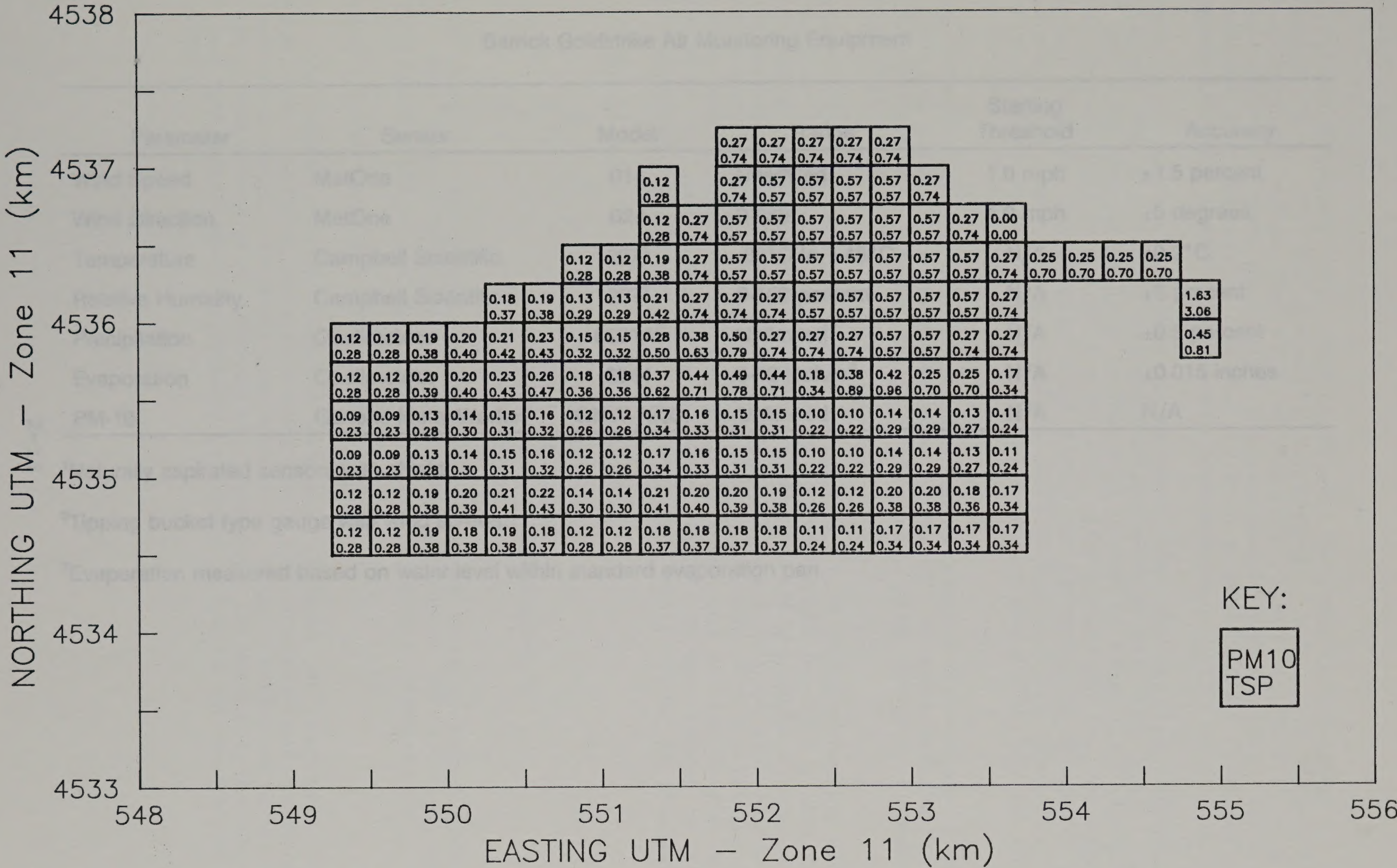


Figure 2-3. Fugitive PM Emissions Apportionment (g/s)

TABLE 2-5

Barrick Goldstrike Air Monitoring Equipment

Parameter	Sensor	Model	Range	Starting Threshold	Accuracy
Wind Speed	MetOne	014	Unlimited	1.0 mph	±1.5 percent
Wind Direction	MetOne	024	0-360°	1.0 mph	±5 degrees
Temperature	Campbell Scientific	207[1]	-33°C to +48°C	N/A	±0.2°C
Relative Humidity	Campbell Scientific	207[1]	0-100 percent	N/A	±5 percent
Precipitation	Qualimetrics	6021A[2]	Unlimited	N/A	±0.5 percent
Evaporation	Qualimetrics	6844	0-10 inches[3]	N/A	±0.015 inches
PM-10	General Metal Works	GMW-1200	Unlimited	N/A	N/A

[1]Naturally aspirated sensors with shield.

[2]Tipping bucket type gauge with wind screen.

[3]Evaporation measured based on water level within standard evaporation pan.

Stability category is a measure of the dispersive capacity of the atmosphere. It is generally separated into six categories (A through F) after the work of Pasquill (1961). Stability A is classified as "very unstable" and represents the greatest level of atmospheric dispersion. Stability F is classified as "stable" and represents the least atmospheric dispersion.

There are several accepted methods for estimating stability category for input to a standard dispersion model (EPA 1987). One of the more common methods is the estimation of stability using the standard deviation of the horizontal wind direction (σ_{θ}, or sigma-theta) and the horizontal wind speed as advanced by Mitchell and Timbre (1979) and Irwin (1980). This procedure was used for the Betze Project data. The method of calculating stability is shown in Tables 2-6 and 2-7.

Sigma-theta was estimated using the standard Yamartino (1984) algorithm using 15-minute average values of the sine and cosine of wind direction stored by the on-site data logger (Campbell Scientific Model CR10).

Approximation of mixing depth, or the vertical volume through which atmospheric dispersion and mixing is permitted to take place, was estimated from historical information on mixing depths measured at Winnemucca, Nevada (Holzworth 1972). These data are summarized in Table 2-8. No local data from the Elko area are available for mixing depth. The climatological values for mixing depth were adjusted to derive hourly mixing depth values based on the estimated stability category for any particular hour as follows:

Stability	Mixing Depth
A	1.5 * PM Height
B,C	1.0 * PM Height
D	(PM Height + AM Height)/2
E,F	1.0 * AM Height

Note that for ground-level emission sources such as those modeled for the Betze Project, exact specification of mixing depth introduces little, if any, error into the model predictions.

2.3.3 Worst-Case Day Selection

For the modeling of 24-hour average impacts of fugitive dust emissions, analyses were conducted only for preselected worst-case dispersion days. Because the executing of a dispersion model for a large combination of sources and receptors is resource-intensive, it was not considered necessary to model all days in the period of record.

TABLE 2-6

PASQUILL STABILITY CATEGORIES
VERSUS HORIZONTAL WIND DIRECTION FLUCTUATIONS, σ_θ

Stability Category	Range of Standard Deviation, Degrees[1]
A (Extremely Unstable)	$\sigma_\theta \geq 22.5$
B (Unstable)	$22.5 > \sigma_\theta \geq 17.5$
C (Slightly Unstable)	$17.5 > \sigma_\theta \geq 12.5$
D (Neutral)	$12.5 > \sigma_\theta \geq 7.5$
E (Slightly Stable)	$7.5 > \sigma_\theta \geq 3.8$
F (Stable)	$3.8 > \sigma_\theta$

Source: EPA (1987)

[1] The table values σ_θ should be adjusted for surface roughness by multiplying each of the values in the table by $(z_o/15\ \text{cm})^{0.2}$ where z_o is the average surface roughness length within a 3 km radius of the source. The surface roughness length was assumed to be 1 cm for purposes of the analysis.

TABLE 2-7

WIND SPEED ADJUSTMENTS FOR DETERMINING FINAL ESTIMATE OF PASQUILL STABILITY CATEGORY FROM σ_θ

	Initial Estimated Stability Category Based on Table 2-6	10m Scalar Wind Speed (u) M/S	10m Scalar Wind Speed (u) MPH	Final Estimate of Stability Category
Daytime	A	$u < 3.0$	$u < 6.0$	A
		$3.0 \leq u < 4.0$	$6.6 \leq u < 8.8$	B
		$4.0 \leq u < 6.0$	$8.8 \leq u < 13.3$	C
		$6.0 \leq u$	$13.3 \leq u$	D
	B	$u < 4$	$u < 8.8$	B
		$4 \leq u < 6$	$8.8 \leq u < 13.3$	C
		$6 \leq u$	$13.3 \leq u$	D
	C	< 6	$u < 13.3$	C
		$6 \leq u$	$13.3 \leq u$	D
	D,E,or F	Any	Any	D
Nighttime	A	$u < 2.9$	$u < 6.4$	F
		$2.9 \leq u < 3.6$	$6.4 \leq u < 7.9$	E
		$3.6 \leq u$	$7.9 \leq u$	D
	B	$u < 2.4$	$u < 5.3$	F
		$2.4 \leq u < 3.0$	$5.3 \leq u < 6.6$	E
		$3.0 \leq u$	$6.6 \leq u$	D
	C	$u < 2.4$	$u < 5.3$	E
		$2.4 \leq u$	$5.3 \leq u$	D
	D	Any	Any	D
	E	$u < 5.0$	$u < 10.5$	E
		$5.0 \leq u$	$10.5 \leq u$	D
	F	$u < 3.0$	$u < 6.6$	F
		$3.0 \leq u < 5.0$	$6.6 \leq u < 10.5$	E
		$5.0 \leq u$	$10.5 \leq u$	D

Source: EPA (1987).

TABLE 2-8

Seasonal Mixing Depth Data - Winnemucca, Nevada

	Morning Height (meters)	Afternoon Height (meters)
Winter	301	1,067
Spring	434	2,756
Summer	129	3,656
Fall	255	2,150

From: Holzworth (1972).

The criteria used for selection of worst-case dispersion days for analysis are listed below.

- Winds were persistent from a single wind sector (45° width) for more than 12 hours.
- Days were selected with the highest frequency of winds in high wind-speed categories.
- Days with winds from all wind-direction sectors were chosen.
- The days selected were compared, when possible, to measured PM-10 levels to confirm potential for elevated particulate concentrations.

For modeling of annual average concentrations, a wind frequency distribution was developed based upon the entire 1-year data base. This distribution segregates dispersion conditions by wind direction, wind speed, and stability category. The model estimates concentrations for each dispersion condition which is then multiplied by the frequency of occurrence of this condition. The total concentration at each receptor is then summed over all possible dispersion conditions.

2.4 Receptor Selection

Air quality concentrations apply to areas of "public access." Under EPA policy, an area is assumed to have the possibility of public access, unless there is a fence or other physical barrier which prohibits the public from entering the property. These barriers may also be natural features such as terrain or bodies of water.

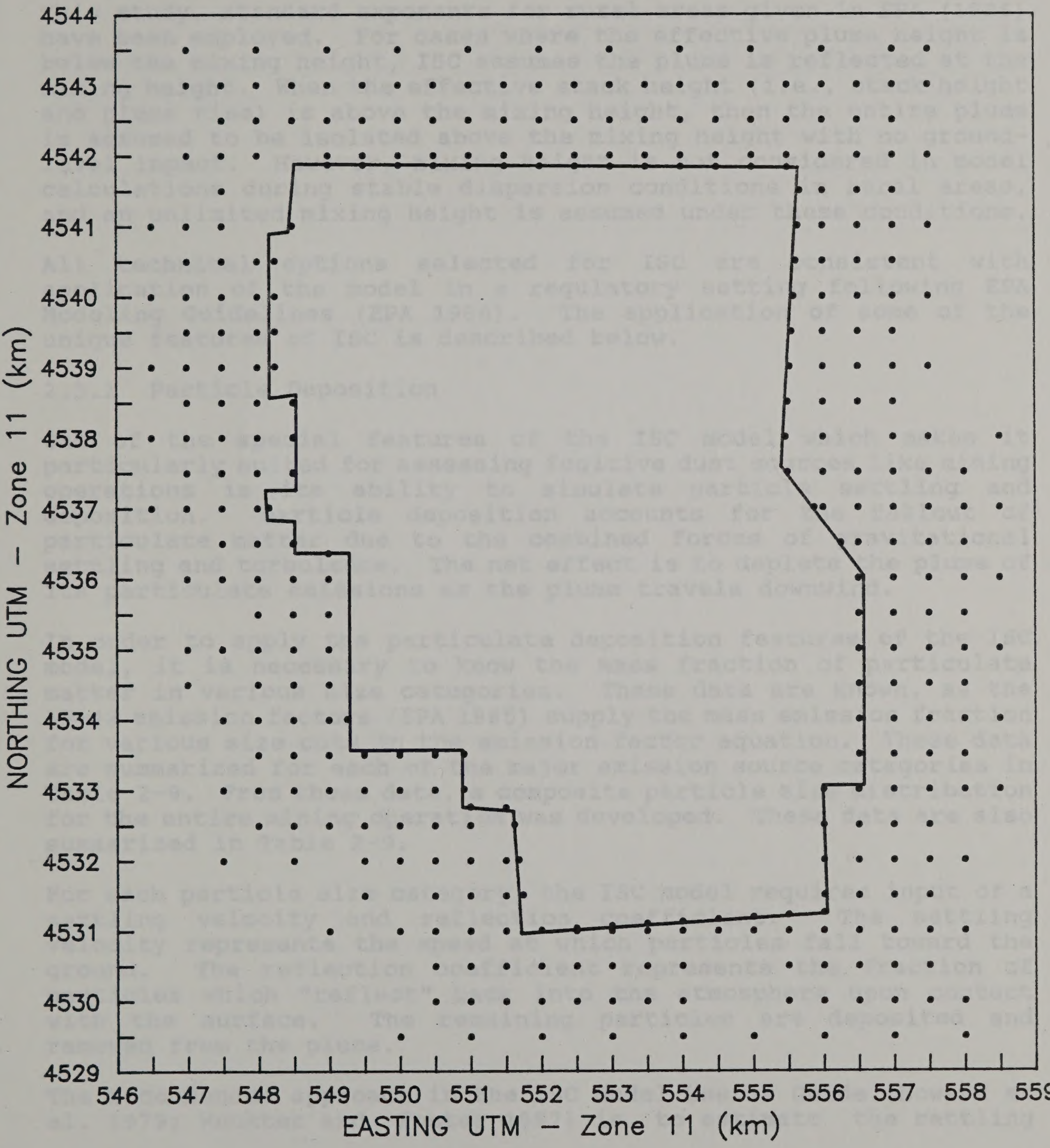
Receptors for the Betze Project modeling were placed at the closest points of public access to the mining operations. This is depicted graphically in Figure 2-5. The receptor grid spacing is 500 meters on a cartesian coordinate system. Receptor elevations were input to the model for each location based upon topographic maps of the area.

2.5 Model Selection and Application

The air quality impact analysis of the Betze Project was conducted using the EPA Industrial Source Complex (ISC) model (Bowers et al. 1979; Wackter and Foster 1986). ISC is well suited for this analysis because it permits treatment of several features unique to mining operations such as particle deposition and wind speed dependent emissions. The application of these features is described later in this section.

FIGURE 2-5.

BARRICK GOLDSTRIKE RECEPTOR GRID



ISC uses horizontal and vertical dispersion parameters as described in Pasquill (1961) and Gifford (1960). A virtual point source approach is used to simulate dispersion of area source emissions. Plume rise for point sources is calculated using the methods of Briggs (1969, 1971, 1975). Required meteorological input data include values of wind shear profile equations and exponents. For this study, standard exponents for rural areas given in EPA (1986) have been employed. For cases where the effective plume height is below the mixing height, ISC assumes the plume is reflected at the mixing height. When the effective stack height (i.e., stack height and plume rise) is above the mixing height, then the entire plume is assumed to be isolated above the mixing height with no ground-level impact. However, mixing height is not considered in model calculations during stable dispersion conditions in rural areas, and an unlimited mixing height is assumed under these conditions.

All technical options selected for ISC are consistent with application of the model in a regulatory setting following EPA Modeling Guidelines (EPA 1986). The application of some of the unique features of ISC is described below.

2.5.1 Particle Deposition

One of the special features of the ISC model which makes it particularly suited for assessing fugitive dust sources like mining operations is its ability to simulate particle settling and deposition. Particle deposition accounts for the fallout of particulate matter due to the combined forces of gravitational settling and turbulence. The net effect is to deplete the plume of its particulate emissions as the plume travels downwind.

In order to apply the particulate deposition features of the ISC model, it is necessary to know the mass fraction of particulate matter in various size categories. These data are known, as the AP-42 emission factors (EPA 1985) supply the mass emission fraction for various size cuts in the emission factor equation. These data are summarized for each of the major emission source categories in Table 2-9. From these data, a composite particle size distribution for the entire mining operation was developed. These data are also summarized in Table 2-9.

For each particle size category, the ISC model requires input of a settling velocity and reflection coefficient. The settling velocity represents the speed at which particles fall toward the ground. The reflection coefficient represents the fraction of particles which "reflect" back into the atmosphere upon contact with the surface. The remaining particles are deposited and removed from the plume.

The recommended approach in the ISC Model User's Guide (Bowers et al. 1979; Wackter and Foster 1987) is to estimate the settling

TABLE 2-9

Betze Project Particle Size Distribution Data
(Mass Fraction Within Each Particle Size Category)

	Diameter (μm)					
Process	<2.5	2.5-5.0	5.0-10.0	10.0-15.0	15.0-30.0	>30.0
Batch Drop Material Handling[1]	0.13	0.10	0.13	0.12	0.25	0.27
Unpaved Roads[2]	0.095	0.105	0.16	0.14	0.3	0.2
Composite	0.1125	0.1025	0.1450	0.1300	0.2750	0.2350

[1]From AP-42 Section 11.2.1

[2]From AP-42 Section 11.2.3, Table 11.2.3-2.

velocity based on Stokes Law and the reflection coefficient as a function of settling velocity based on empirical data (Dumbald 1976). However, this approach is technically deficient because it considers gravitational forces only and ignores the effect of turbulent deposition on particle settling. Turbulent deposition has been documented as being the primary component of particle fallout for smaller particle sizes (Horst 1979; Ermak 1977).

The ISC treatment of particle deposition can be improved by replacing the Stokes Law settling velocity with a more realistic "deposition velocity," which accounts for both gravitational settling and turbulent deposition of smaller particles. In this study, values of deposition velocity were taken from curves developed by Sehmel and Hodgson (1980), which are shown in Figure 2-6. Here, deposition velocity is a function of particle size and the friction velocity (U*). For the Betze Project analyses, a U* value of 30 cm/sec was assumed.

Further refinement to the traditional ISC treatment of particle deposition has been made to the reflection coefficient. The Dumbald (1976) study upon which the ISC manual procedure is based was derived from field studies on the Salt Flats of western Utah. This is a highly idealized and smooth surface, and experimental data from the Salt Flats is not automatically transferable to other situations. The ISC-derived reflection coefficient is adjusted based on the local surface drag coefficient (Cg) according to the following formulation:

$$\frac{Cg\ (\text{local})}{Cg\ (\text{Salt Flats})} = \frac{(1 - d)_l/(1 + d)_l}{(1 - d)_{sf}/(1 + d)_{sf}}$$

where d is the reflection coefficient.

The deposition velocities and reflection coefficients input to the ISC model for each particle size category following the improved methodology are listed in Table 2-10.

2.5.2 Pit Retention

Pit retention refers to the fact that not all emissions which are released at surface mining operations actually escape the pit and impact the ambient air. Many pit emissions occur below ground-level, causing particulate to be trapped within the pit. This is especially true of larger-sized particles, which are affected by the phenomena of gravitational settling and turbulent deposition which was discussed previously.

For the Betze Project air quality studies, the pit operations were divided into two areas: 1) in-pit operations and 2) rim operations. In-pit operations included activities generally associated with the bottom of the mine pit like blasting and truck

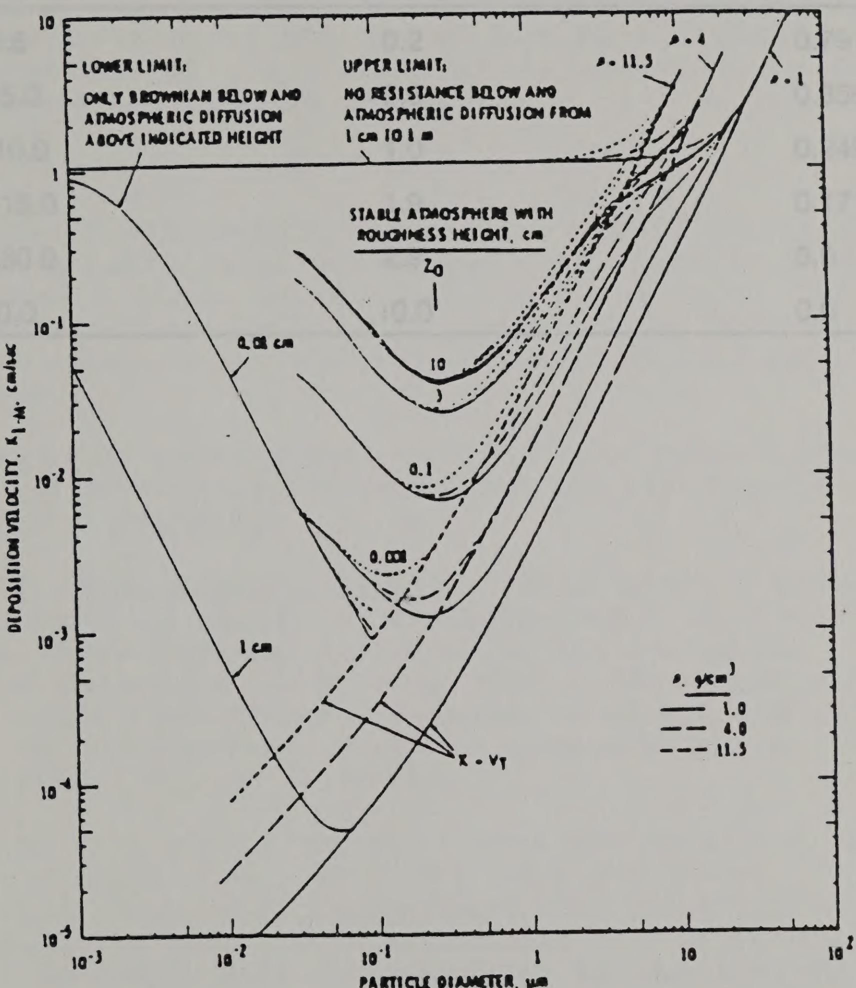


Figure 2-6. Predicted Deposition Velocities at 1 meter for U_*=30 cm/sec and particle densities of 1, 4, and 11.5 g/cm^3 (After Sehmel and Hodgson 1980)

TABLE 2-10

Deposition Velocities and Reflection Coefficients
Input to Betze Project ISC Modeling

Size Range (μm)	Deposition Velocity (cm/s)	Reflection Coefficient
<2.5	0.2	0.791
2.5-5.0	0.6	0.656
5.0-10.0	1.0	0.249
10.0-15.0	1.9	0.171
15.0-30.0	2.9	0.0
>30.0	10.0	0.0

loading of ore and waste. Other operations like haul truck traffic and wind erosion from disturbed areas were assumed to occur uniformly across all pit grid squares, including the rim.

The pit rim grid squares were those grids on the outer boundary of the pit. Since these grids include the entry/exit roads to the pit and are only partially depressed into the surface, no pit retention was assumed for these grids. For the in-pit grid squares, it was assumed that all particles sized 10 microns and larger are retained in the pit as well as 20 percent of the PM-10 fraction emissions. This distribution of pit retention is reported in Cole et al. (1989) and Cole and Fabrick (1984).

2.5.3 Wind Speed Dependent Emissions

Emissions from fugitive dust sources are highly variable with time. Often, this variability is associated with climatic conditions. In the ISC model, there is a feature to account for emissions variability as a function of wind speed. This feature was used to simulate the temporal variability in fugitive dust emissions at the Betze Project.

The fugitive dust sources were divided into three categories, and the wind speed variability of emissions was developed independently for each source category.

2.5.3.1 <u>Wind Erosion Sources</u>. Wind erosion sources include open dust areas such as ore pits, waste areas, open stockpiles, and other areas where surface disturbance has occurred. In general, wind erosion emissions only occur when a threshold wind speed is exceeded. Below this threshold speed, wind erosion emissions are zero. The threshold wind speed is commonly set at 12 miles per hour (mph) (EPA 1977, 1979, 1985).

The emissions from wind erosion sources are generally expressed as long-term averages, i.e., tons per acre per year. It is assumed that emissions calculated using these factors occur over all time periods, including when the wind is below the threshold speed. The mean annual emission rate is converted to the appropriate hourly emission rate based on the frequency of winds exceeding the 12 mph threshold. For example, if the windrose shows hourly average winds exceeding 12 mph for 20 percent of the time, then the hourly wind erosion emissions are estimated at 5 times (1/0.2) the annual mean emissions calculated using the emission factor. For periods when the mean wind speeds are below the 12 mph threshold, zero wind erosion emissions are assumed. When applied over the entire annual wind distribution, this method reproduces the total annual emissions, but provides a more realistic hour-to-hour distribution of these emissions.

2.5.3.2 <u>Materials Handling Sources</u>. Materials handling emission sources include operations such as truck loading/unloading

of ore and waste, stockpile loading via conveyor, or other open air material transfer operations.

For materials handling sources, the emissions are assumed to be linearly proportional to wind speed. This linear dependence is derived from the AP-42 emission factor document. The emission factor equations in AP-42 Section 11 for materials handling sources set a linear dependence of emissions with wind speed. For materials handling sources, the hourly emissions are calculated based on the ratio of the hourly wind speed to the annual mean wind speed. For example, if the annual mean wind speed at the site is 10 mph, the source emissions would be one-half the annual mean emission rate when the wind speed is half the annual mean or 5 mph, but twice the annual mean emission for hours with wind speeds that are twice the annual mean, or 20 mph. Again, this method preserves the annual mean emission rate calculated using the emission factor, but allows the real-life variability of fugitive dust emissions to be more accurately simulated.

2.5.3.3 Other Sources. For other fugitive dust sources at mining operations, there is no known dependence of emissions on wind speed. This includes drilling, blasting, haul roads, etc. Therefore, for these source categories, no variability of emissions with wind speed is included in the modeling. Instead, the annual mean emissions are assumed to occur uniformly over each hour of the year.

3.0 CUMULATIVE ANALYSIS

The proposed Betze Project is located in an area already impacted by mining development with several active mining operations present in the vicinity. This may cause a cumulative impact on air quality which could exceed the impact of any single project alone.

The other nearby sources in the region considered in the cumulative assessment include:

- Dee Gold, Boulder Creek Project
- Newmont Gold, Mill #4
- Newmont Gold, North Heap Leach
- Universal Gas, Primary Crusher
- Newmont Gold, Mill #1 (Carlin)

These sources include fugitive emissions from mining and heap leach operations, point source emissions from crushers and other ore handling/processing operations, and mobile source emissions from mining equipment. In general, these other operations are smaller in scope than the proposed Betze Project, so emissions from any nearby operations will be much less than described earlier for the Betze Project.

Fugitive dust emissions typically impact only a very small area. As explained previously, most fugitive dust emissions consist of larger particles which fall out of the plume due to the combined processes of gravitational settling and turbulent deposition. This depletes the plume of emission material and causes very sharp concentration gradients downwind of the source. Figure 3-1 shows source depletion for a ground level source. Worst-case fugitive dust impacts will occur at higher wind speeds, resulting in neutral (D stability) conditions. The curve for stability in Figure 3-1 demonstrates the sharp plume depletion gradient immediately downwind of a fugitive source. Calculations show that only approximately 40 percent of the initial emissions from a ground-level fugitive dust source remain in the plume at a downwind distance of 1 kilometer under D stability, 5 meter-per-second winds, and 5 centimeter-per-second settling velocity (EPA 1978). Measured plume depletion studies have shown a 79 percent reduction in TSP emission rates over a distance of 100 m (EPA 1981). Since the closest non-Barrick fugitive dust sources of appreciable size around the proposed Barrick operation are no closer than 2 kilometers, it is not necessary to explicitly include neighboring fugitive dust sources in the modeling study. Fugitive dust sources at other nearby operations are at too great a distance downwind to have any appreciable impact on the Betze Project region. Furthermore, these emissions are smaller in magnitude than the Betze Project emissions and will themselves have less of an impact.

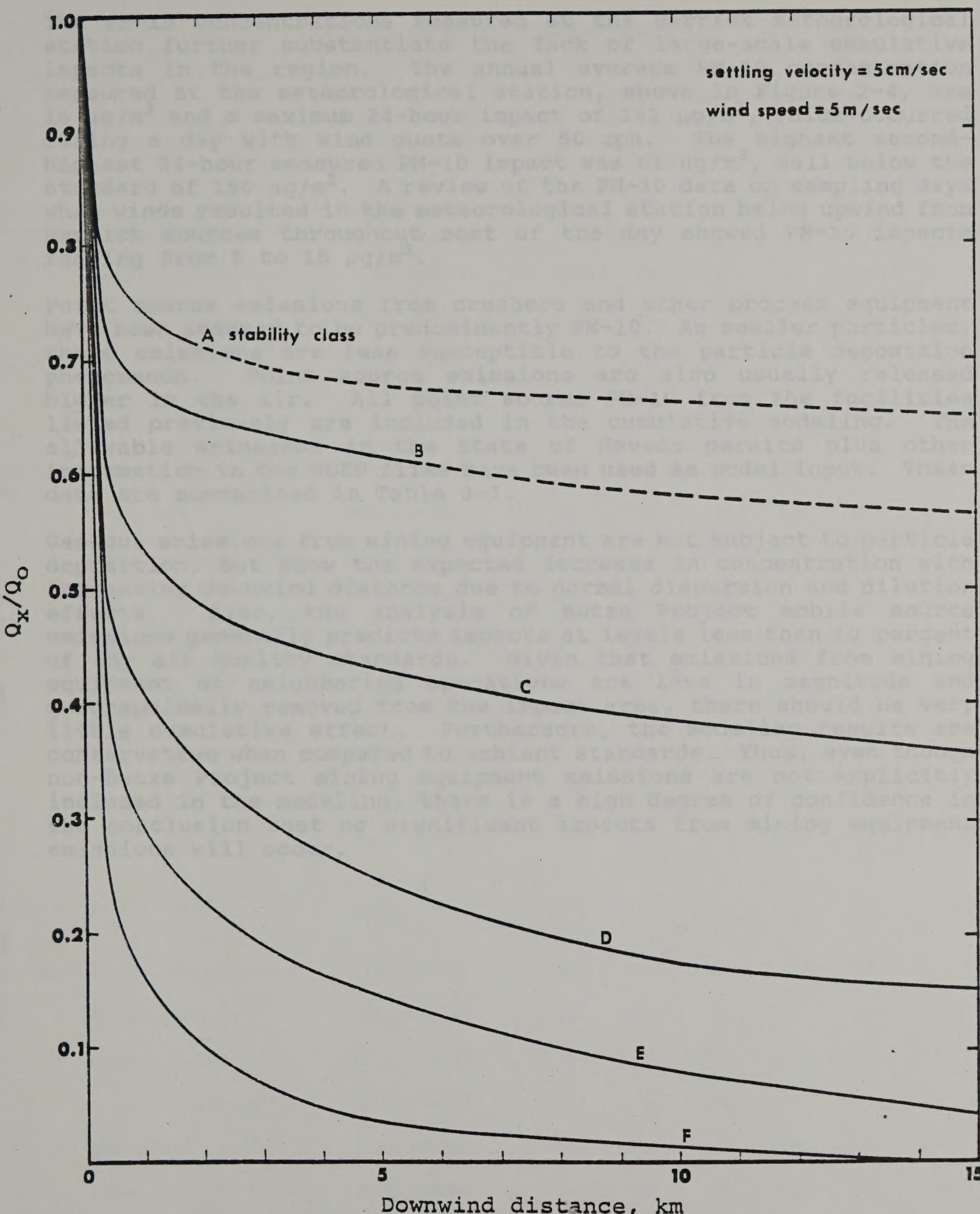


Figure 3-1. Source depletion factors by stability class for ground level sources.

Source: U.S. Atomic Energy Commission

The PM-10 concentrations measured at the Barrick meteorological station further substantiate the lack of large-scale cumulative impacts in the region. The annual average PM-10 concentration measured at the meteorological station, shown in Figure 2-4, was 16 $\mu g/m^3$ and a maximum 24-hour impact of 142 $\mu g/m^3$, which occurred during a day with wind gusts over 50 mph. The highest second-highest 24-hour measured PM-10 impact was 61 $\mu g/m^3$, well below the standard of 150 $\mu g/m^3$. A review of the PM-10 data on sampling days when winds resulted in the meteorological station being upwind from Barrick sources throughout most of the day showed PM-10 impacts ranging from 5 to 15 $\mu g/m^3$.

Point source emissions from crushers and other process equipment have been assumed to be predominantly PM-10. As smaller particles, these emissions are less susceptible to the particle deposition phenomenon. Point source emissions are also usually released higher in the air. All point source PM-10 from the facilities listed previously are included in the cumulative modeling. The allowable emissions in the State of Nevada permits plus other information in the NDEP files have been used as model input. These data are summarized in Table 3-1.

Gaseous emissions from mining equipment are not subject to particle deposition, but show the expected decrease in concentration with increasing downwind distance due to normal dispersion and dilution effects. Also, the analysis of Betze Project mobile source emissions generally predicts impacts at levels less than 10 percent of any air quality standards. Given that emissions from mining equipment at neighboring operations are less in magnitude and geographically removed from the impact area, there should be very little cumulative effect. Furthermore, the modeling results are conservative when compared to ambient standards. Thus, even though non-Betze Project mining equipment emissions are not explicitly included in the modeling, there is a high degree of confidence in the conclusion that no significant impacts from mining equipment emissions will occur.

Table 3-1

Little Boulder Basin Gold Processing Facilities

COMPANY NAME	SOURCE	UTM-EAST (m)	UTM-NORTH (m)	ELEVATION (ft)	OPERATING HOURS	STACK HEIGHT (m)	STACK DIAM. (m)	STACK TEMP. (K)	STACK VELOC. (m/s)	ALLOWABLE TSP (g/s)
Dee Gold/ Boulder Creek	Jaw crusher, screen, cone crusher, conveyor, ore bin.	548540	4541420	5460	3500	10	0.9	293	12	7.17
	Carbon regeneration kiln.	548540	4541420	5460	4015	17.5	0.3	978	16.8	0.13
	Induction furnace.	548540	4541420	5460	1464	10	0.25	339	7	0.06
	Lime storage bin.	548540	4541420	5460	8760	10	0.01	293	0.01	0.09
	Cyanide storage bin.	548540	4541420	5460	1095	10	0.3	293	6.9	2.78
Newmont Gold/ Mill 4	Gyratory Crusher.	554190	4536720	5489	8760	10	0.01	293	0.01	8.19
	Cement Silo.	554290	4536470	5507	8760	10	0.3	293	6.6	0.03
	Reclaim tunnel apron feeder.	554670	4537760	5581	8760	7	1.3	293	3.8	0.11
	Lime bin.	554590	4537780	5580	8760	10	0.3	293	6.9	0.003
	Secondary cone crusher.	554530	4537740	5609	8760	7	1.3	293	3.8	0.09
Newmont Gold/ N. Heap Leach	Gyratory crusher.	554240	4533650	5660	8760	10	0.9	293	5.1	2.52
	Two cone crushers.	554290	4533670	5660	8760	10	0.9	293	5.1	1.9
	Two screens.	554290	4533670	5660	8760	10	0.9	293	5.1	0.67
	Cement bin.	554480	4533710	5590	7000	10	0.01	293	0.01	0.01
Universal Gas	Primary crusher	554720	4530360	5860	1400	14	0.01	294	0.01	6.45
Newmont Gold/ Mill 1, Carlin	Jaw/cone crushers, screens	557380	4529260	6280	8760	5.8	0.9	294	12.3	7.67
	Carbon ore plant.	557320	4529260	6280	8760	21.6	0.3	294	20	0.83
	Lime bin - load	557340	4529200	6280	8760	12.5	0.2	294	0.01	0.05
	Lime bin - discharge	557340	4529200	6280	8760	10	0.01	294	0.01	0.003
	Chlorination	557250	4529205	6280	8760	10	0.01	294	0.01	0.003
	Process boiler	557400	4529200	6280	8760	4.6	0.6	422	4.2	1.14
	Facility boiler #1	557320	4529260	6280	8760	14.6	0.4	422	4.2	0.39
	Facility Boiler #2	557320	4529265	6280	8760	14.6	0.4	422	4.2	0.39

4.0 RESULTS AND DISCUSSION

4.1 Particulate

Figures 4-1 through 4-4 show modeled PM-10 and TSP particulate concentrations in the Betze Project area. The results of the modeling study including background (both natural and that attributable to existing sources) are shown in Table 4-1. The maximum 24-hour impacts, as predicted for receptors located at the fenced boundary of the active mining area, are 111 micrograms per cubic meter ($\mu g/m^3$) for PM-10 and 128 $\mu g/m^3$ for TSP. The predicted annual maximum concentrations are 49 $\mu g/m^3$ for PM-10 and 48 $\mu g/m^3$ for TSP. The annual PM-10 maximum concentration is higher than the annual TSP maximum concentration because the PM-10 concentration is an arithmetic average and the TSP concentration is a geometric mean. The predicted air quality impacts at these receptors are below the federal PM-10 standards and Nevada TSP standards.

4.2 Carbon Monoxide

The air quality impact from CO emissions from the Betze Project were predicted by modeling the emissions using the EPA's ISC dispersion model, with on-site meteorological data as input. The results of the modeling study are shown in Table 4-2. The modeled maximum 1-hour impact from Barrick sources was 429 micrograms per cubic meter ($\mu g/m^3$). The modeled maximum 8-hour impact from Barrick sources was 164 $\mu g/m^3$. The modeled impacts are well below the federal and Nevada air quality 1-hour standard of 40,000 $\mu g/m^3$, and the 8-hour standard of 10,000 $\mu g/m^3$.

4.3 Nitrogen Dioxide

The air quality impact from NO_2 emissions from the Betze Project were predicted by modeling the emissions using the EPA's ISCST dispersion model, with on-site meteorological data as input. The results of the modeling study are shown in Table 4-2. The modeled annual impact from Barrick sources was 17 $\mu g/m^3$. The modeled impact is well below the federal and Nevada air quality annual standard of 100 $\mu g/m^3$.

4.4 Sulfur Emissions

The existing autoclave has an emission rate of 0.548 pounds of total sulfur per hour, compared to the allowable rate of 787 pounds per hour. The actual and projected sulfur emissions were not modeled for ambient air quality impacts because the emission rates from these sources are very low.

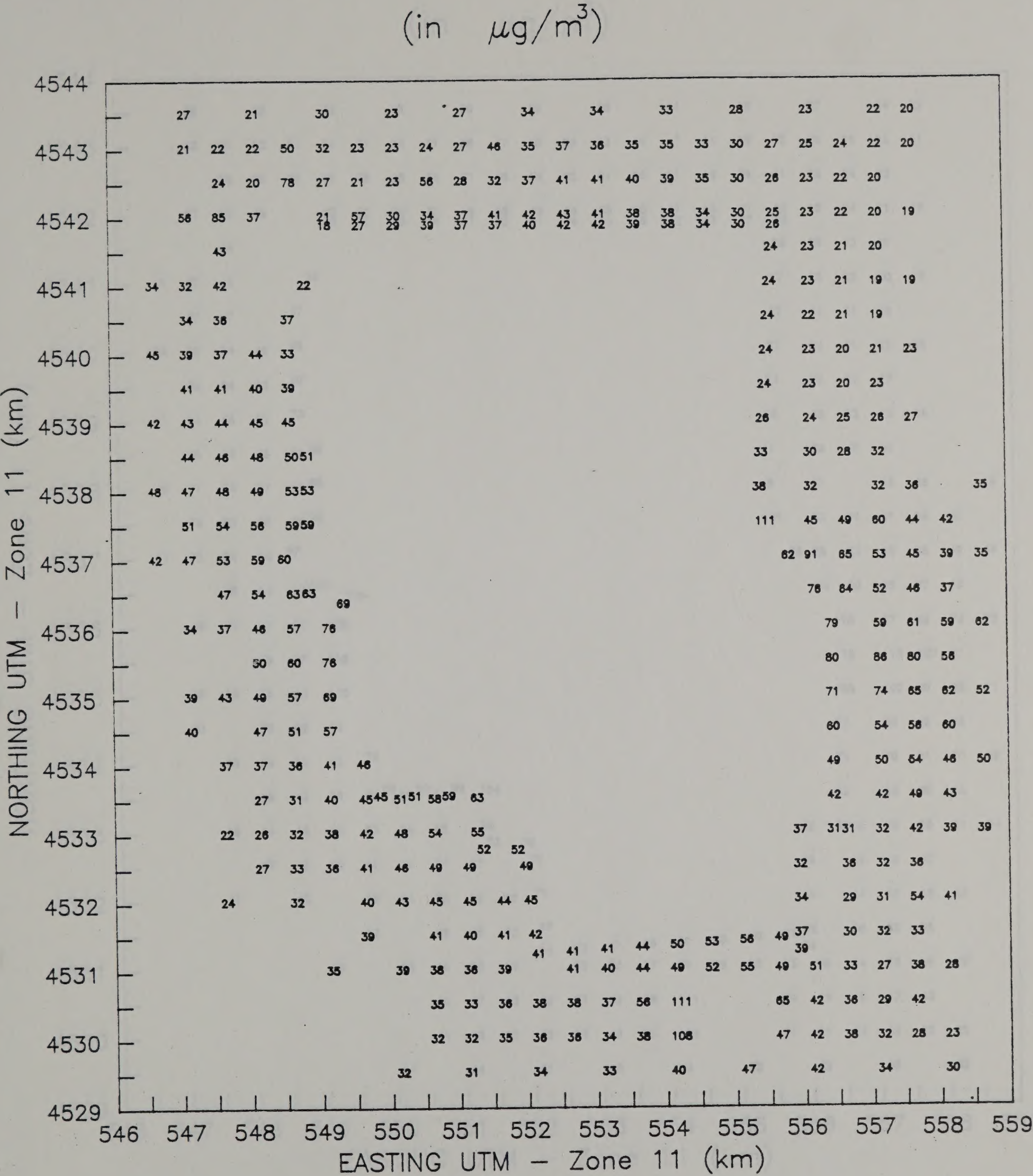


Figure 4-1. Barrick Goldstrike Cumulative PM10 Impacts: 24-Hour

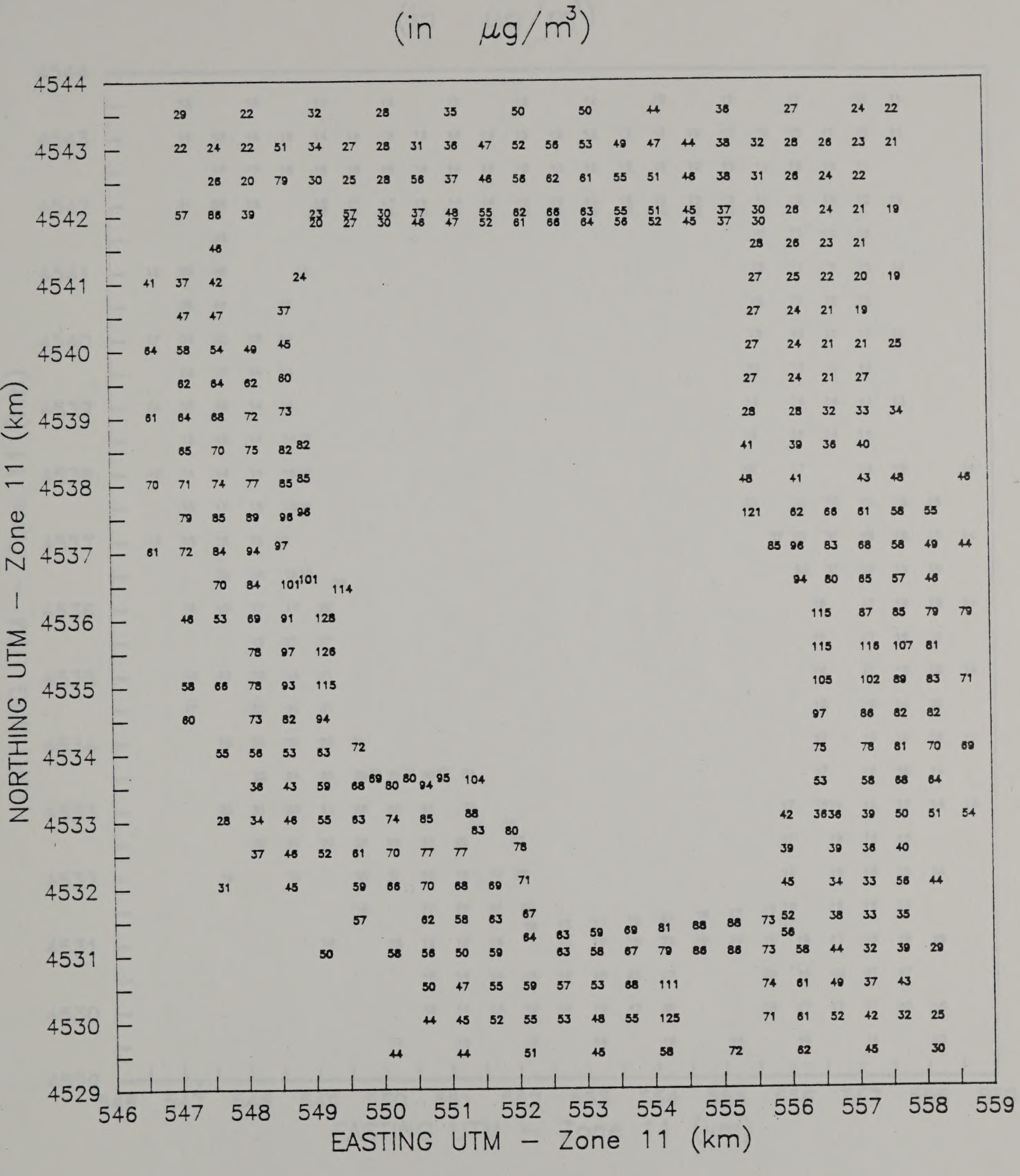


Figure 4-2. Barrick Goldstrike Cumulative TSP Impacts: 24-Hour

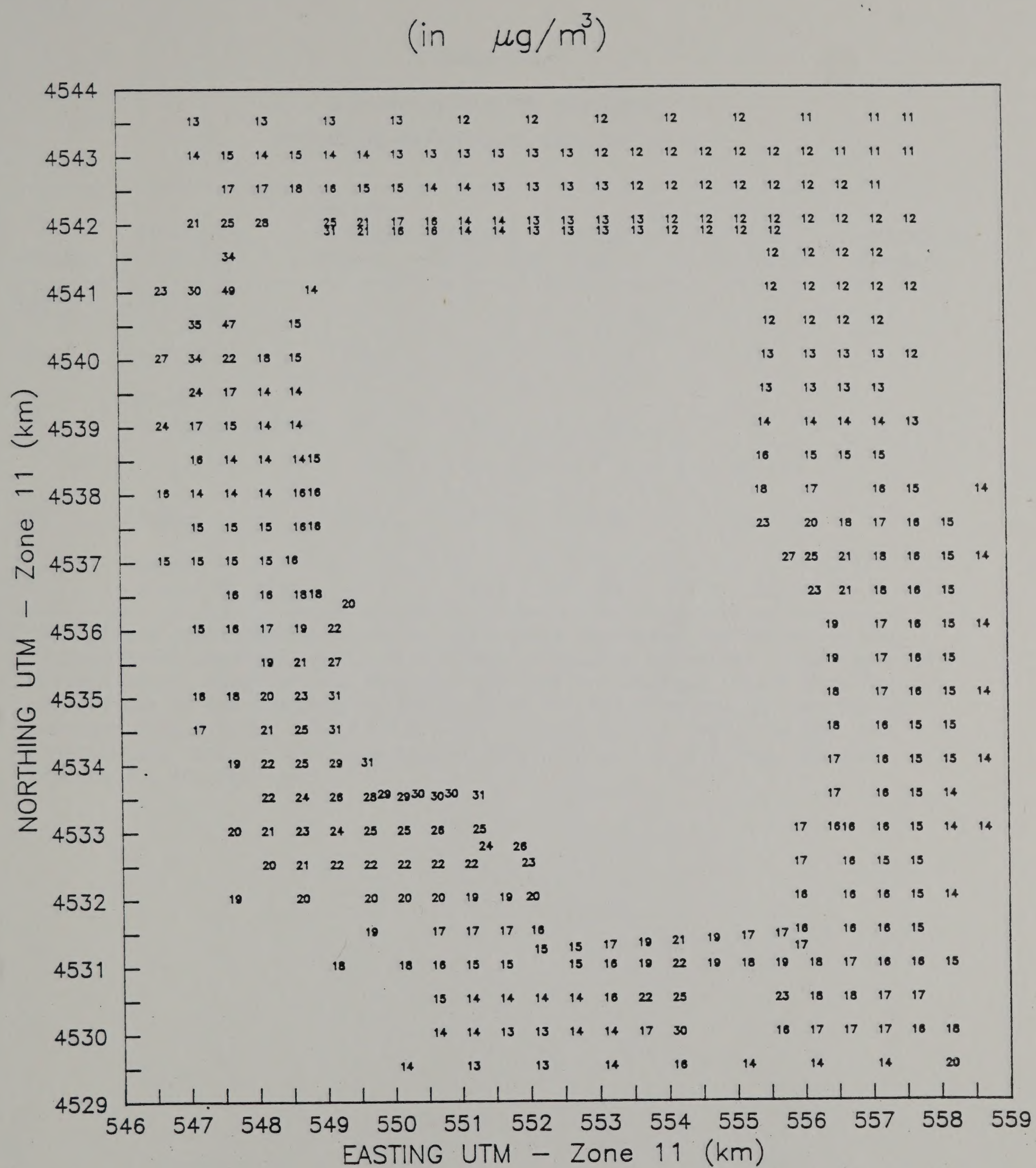


Figure 4-3. Barrick Goldstrike Cumulative PM10 Impacts: Annual

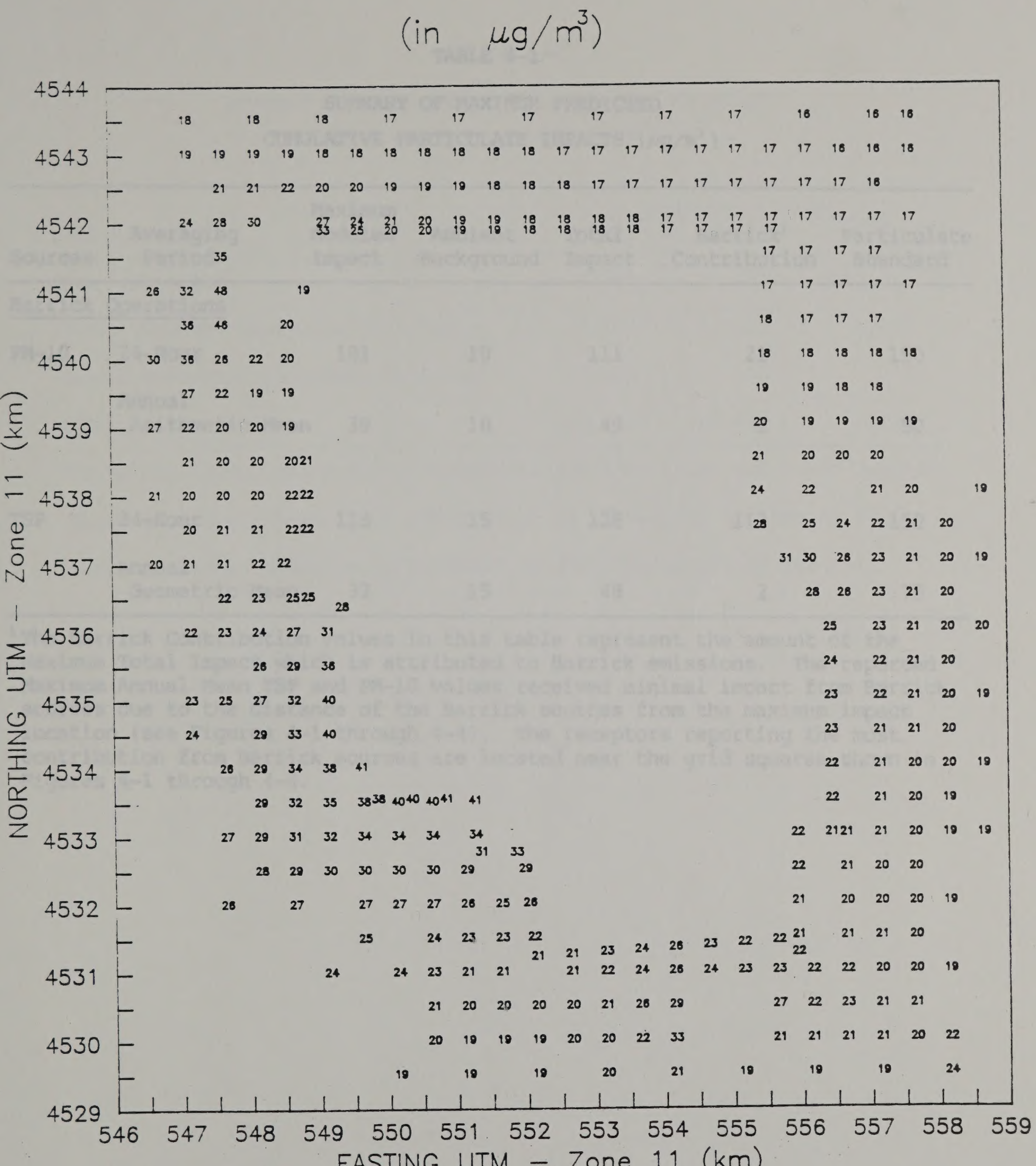


Figure 4-4. Barrick Goldstrike Cumulative TSP Impacts: Annual

TABLE 4-1

SUMMARY OF MAXIMUM PREDICTED

CUMULATIVE PARTICULATE IMPACTS ($\mu g/m^3$)

Sources	Averaging Period	Maximum Modeled Impact	Ambient Background	Total Impact	Barrick[1] Contribution	Particulate Standard
Barrick Operations						
PM-10	24-Hour	101	10	111	21	150
	Annual Arithmetic Mean	39	10	49	2	50
TSP	24-Hour	113	15	128	113	150
	Annual Geometric Mean	33	15	48	2	75

[1] The Barrick Contribution values in this table represent the amount of the Maximum Total Impact which is attributed to Barrick emissions. The reported Maximum Annual Mean TSP and PM-10 values received minimal impact from Barrick sources due to the distance of the Barrick sources from the maximum impact location (see Figures 4-1 through 4-4). The receptors reporting the most contribution from Barrick sources are located near the grid squares shown in Figures 4-1 through 4-4.

TABLE 4-2

SUMMARY OF OTHER PROJECTED POLLUTANT EMISSIONS FROM BARRICK GOLDSTRIKE MINE

Source	Emissions (lb/day)		
	CO	NO_2	SO_2
Ore Processing[1]	100	400	negligible
Diesel-Powered Equipment/Vehicles[2]	5,467	13,107	1,108
Gasoline-Powered Equipment/Vehicles[3]	3,385	82	5
TOTAL	8,952	13,589	1,113

[1] Emissions from propane-fired carbon reactivation kilns and steam boilers.

[2] Based on annual diesel fuel consumption of 13,000,000 gallons of fuel.

[3] Based on annual gasoline consumption of 312,000 gallons of fuel.

4.5 Other Emissions

The ore from the Betze Pit would contain some trace amounts of various metals. To assess the emission levels of such metals from the mining and milling operations, a study of the metals content of the ore and waste rock was conducted. Rock samples were collected from coreholes within the proposed Betze Pit, and the metals content of each sample was determined. The most conservative estimate of the metals content from any of the samples was used in the analysis. The resulting metals concentrations are presented in Table 4-3. The data show that, at most, the metals are present in concentrations that are less than half of the significance levels established by the NDEP. Thus, the concentration of airborne metals is expected to be minimal.

The projected mercury emissions from the existing autoclave is 0.05 lb per 8-hour time-period. The emissions for the existing autoclave were not modeled for ambient air quality impacts because the emission rate was well below the allowable mercury emission rate of 0.25 lb per 8-hour time period. Therefore, no significant impacts are expected.

The cyanidation process would use sodium cyanide in solution at the heap leach pads and in the carbon-in-leach (CIL) circuit at the mill. The solutions are maintained at a high pH using lime and caustic to maintain the cyanide in solution and minimize the formation of hydrogen cyanide (HCN). With the continued pH control of the process solutions, HCN formation and the off-gas of HCN would be negligible; consequently, ambient HCN concentrations are expected to be minimal. There is no NAAQS for HCN.

The nearest Class I area, Jarbidge Wilderness, is more than 70 miles away; no effects from the project are expected on Class I air quality or visibility.

TABLE 4-3

PROJECTED METALS IMPACT ANALYSIS

Metal	Metals Content[1] (ppm)	8-Hour Average Concentration[2] ($\mu g/m^3$)	Significance Level[3] ($\mu g/m^3$)	Percent of Significance Level
Arsenic	5,290	1.12	4.8	24
Barium	1,490	0.32	11.9	2.7
Boron	10	0.002	119	0.002
Cadmium	38	0.008	1.2	0.7
Chromium	84	0.018	1.2	1.5
Copper	192	0.041	23.8	0.2
Iron	47,500	10.1	23.8	42
Lead	85	0.018	3.6	0.5
Mercury	52	0.011	0.2	4.7
Magnesium	19,500	4.1	238	1.7
Manganese	1,050	0.22	119	0.2
Nickel	250	0.053	2.4	2.2
Selenium	20	0.004	4.8	0.1
Silver	4	0.0008	0.2	0.4
Thallium	40	0.008	2.4	0.4

[1] Based on whole rock analysis. Maximum value in any single sample used.

[2] Calculated based on 8-hour average TSP concentration of 212.4 $\mu g/m^3$.

[3] Nevada air toxics standard based on Threshold Limit Value/42.

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APPENDIX A

PM-10 FILTER SAMPLE ANALYSIS

PM-10 FILTER SAMPLE ANALYSIS

Portions of four PM-10 filter samples from the lot collected at the Goldstrike meteorological station depicted on Figure 2-4 were analyzed for elements of potential concern. Although the Goldstrike meteorological station was not originally sited to represent a maximum impact location of Barrick's particulate emissions, these are the only data available and should reflect the type of regional impacts occurring. Modeling results reflect the fact that the location of maximum operation impacts from Barrick should not occur at the PM-10 monitoring site.

The PM-10 filters were analyzed for total arsenic (As), total barium (Ba), total cyanide (CN), weak acid dissociable cyanide (WAD CN), and selenium (Se). These five parameters were chosen based on considerations such as being unique to the mining/processing operations, potential toxicity, and metals content in whole rock analyses of core samples taken from the area of the proposed Betze Pit. The PM-10 filters analyzed were chosen based on measured PM-10 concentrations and wind conditions on the day the sample was collected. Samples were selected for 3 days which represent meteorological conditions indicating potential impacts from Barrick and/or Newmont, and one sample was chosen to reflect background conditions. The samples chosen from February 16, May 14, May 23, and June 10, 1990, were selected for the following reasons:

February 16: The sample collected on this date was the highest PM-10 value measured during the first 9 months of monitoring. Winds were moderate to strong from the south; thus, the Goldstrike meteorological station was downwind of the existing Barrick and Newmont operations.

May 14: The sample collected on this date represents impacts from background sources. The PM-10 value measured is one of the higher background values. Winds were from the northwest through northeast most of the day making the Goldstrike meteorological station upwind of the existing Barrick and Newmont operations.

May 23: The sample collected on this date was one of the higher PM-10 values measured. Winds were from the south and southwest through the middle of the day. The Goldstrike meteorological station was downwind of the existing Barrick and Newmont operations during this period.

June 10: The sample collected on this date had a moderately heavy PM-10 load, and there were moderate to strong winds from the south and southwest. The Goldstrike meteorological station was downwind of the existing Barrick and Newmont operations.

In addition to analyzing the four filters described above, one blank filter was analyzed to determine representative existing concentrations of the elements associated with the filters themselves. Each analysis was then corrected based on the analysis of the "blank" filter.

The filters were analyzed using EPA-approved methodologies listed below:

Compound	EPA Methodology	Type
As	#7060	GFAA
Ba	#6010	ICAP
CN	#9010	Colorometric
Se	#7740	GFAA

The results of the PM-10 filter analyses are presented in Table A-1. Barium concentrations were highest on 2 of the 3 days when winds were from the south and southwest, the direction of the existing Barrick and Newmont operations. Arsenic was detected only on these 2 days, and total cyanide was detected on one of these days. The presence of these elements suggests that some transport and impact from the existing Barrick and Newmont operations occurred on these 2 days. The measured concentrations of As, Ba, CN, and Se during these selected highest particulate impact days at the Goldstrike meteorological station were minimal and would not present a threat to human health. The values reported are orders of magnitude below applicable Nevada air quality standards, which are equal to the corresponding Threshold Limit Values (TLV) divided by 42 (TLV/42).

TABLE A-1

PM-10 FILTER MEASURED COMPOUND/METALS CONCENTRATIONS

GOLDSTRIKE METEOROLOGICAL STATION

Date	Compound/Metal	24-Hour Average Concentration ($\mu g/m^3$)	Significance Level[1] ($\mu g/m^3$)	Percent of Significance Level
2/16/90	Total CN	<0.007[2]	119.0	<0.006
	WAD CN[3]	<0.007	119.0	<0.006
	Total As	0.03	4.8	0.6
	Total Ba	0.04	11.9	0.3
	Total Se	<0.01	4.8	<0.2
5/14/90[4]	Total CN	<0.007	119.0	<0.006
	WAD CN	<0.007	119.0	<0.006
	Total As	<0.007	4.8	<0.1
	Total Ba	0.006	11.9	0.05
	Total Se	<0.01	4.8	<0.2
5/23/90	Total CN	0.01	119.0	0.008
	WAD CN	<0.007	119.0	<0.006
	Total As	0.03	4.8	0.6
	Total Ba	0.01	11.9	0.08
	Total Se	<0.01	4.8	<0.2
6/10/90	Total CN	<0.007	119.0	<0.006
	WAD CN	<0.007	119.0	<0.006
	Total As	<0.007	4.8	<0.1
	Total Ba	0.006	11.9	0.05
	Total Se	<0.01	4.8	<0.2

[1] Nevada air toxics standard based on TLV/42.

[2] "<" denotes less than detection limit.

[3] Weak Acid Dissociable cyanide represents cyanide which can be dissociated in the laboratory using a weak acid at a pH of 4.5, meaning the cyanide is more susceptible to dissociation and the formation of HCN. Total cyanide is detected in the laboratory by using a stronger acid solution at pH less than 2.0 and, therefore, represents cyanide in a relatively stable condition.

[4] Represents local background levels.